Geological Survey
of Canada

Current Research
2001-A13

Evidence for a Late Quaternary outburst flood event in the Georgia Basin, British Columbia

K.W. Conway, J.V. Barrie, and R.J. Hebda

2001

Natural Resources Canada Ressources naturelles Canada

©Her Majesty the Queen in Right of Canada, 2001
Catalogue No. M44-2001/A13E
ISBN 0-660-18393-5

Available in Canada from the
Geological Survey of Canada Bookstore website at:
http://www.nrcan.gc.ca/gsc/bookstore (Toll-free: 1-888-252-4301)

A copy of this publication is also available for reference by depository libraries across Canada through access to the Depository Services Program's website at http://dsp-psd.pwgsc.gc.ca

Price subject to change without notice

All requests for permission to reproduce this work, in whole or in part, for purposes of commercial use, resale, or redistribution shall be addressed to: Earth Sciences Sector Information Division, Room 200, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Authors' addresses

K.W. Conway *(kconway@nrcan.gc.ca)*
J.V. Barrie *(vbarrie@nrcan.gc.ca)*
GSC Pacific, Sidney
9860 West Saanich Road
Victoria, British Columbia V8L 4B2

R.J. Hebda *(rhebda@royalbcmuseum.bc.ca)*
Royal British Columbia Museum
625 Belleville Street
Victoria, British Columbia V8W 9W2

Evidence for a Late Quaternary outburst flood event in the Georgia Basin, British Columbia

K.W. Conway, J.V. Barrie, and R.J. Hebda
GSC Pacific, Sidney

Conway, K.W., Barrie, J.V., and Hebda, R.J., 2001: Evidence for a Late Quaternary outburst flood event in the Georgia Basin, British Columbia; Geological Survey of Canada, Current Research 2001-A13, 6 p.

Abstract Coring of Late Quaternary sediments in the Georgia Basin has revealed stratigraphic and micropalcontological evidence of an outburst flood that deposited a clay layer over much of the seafloor of the Strait of Georgia. The flood originated in the Fraser Valley or the British Columbia interior during deglaciation when an ice-dammed lake or lakes drained catastrophically. A reworked pollen assemblage contained within the clay unit has a source in the Fraser Valley or the British Columbia interior. The clay unit contains a characteristic grain-size signature, sedimentary structures, and a radiocarbon chronology consistent with a rapidly deposited unit emplaced by a flood event. Diatom assemblages show that a markedly lower salinity of surface waters accompanied deposition. Radiocarbon dating indicates that the flood occurred between 9160 and 9800 radiocarbon years BP. The unit correlates well with a somewhat thicker deposit found at Ocean Drilling Program drilling sites in Saanich Inlet.

Résumé Le carottage des sédiments du Quaternaire supérieur du bassin de Georgia a permis de recueillir des preuves stratigraphiques et micropaléontologiques qu'une inondation catastrophique avait déposé une couche d'argile sur une bonne partie du fond marin du détroit de Georgia. L'inondation a commencé dans la vallée du Fraser ou à l'intérieur de la Colombie-Britannique durant la déglaciation lorsqu'au moins un lac de barrage glaciaire s'est vidé d'une façon catastrophique. L'assemblage pollinique remanié contenu dans l'unité argileuse provient de la vallée du Fraser ou de l'intérieur de la Colombie-Britannique. La signature granulométrique caractéristique de l'unité argileuse, les structures sédimentaires et la chronologie par radiocarbone permettent en effet de conclure qu'une unité a été déposée rapidement par suite d'une inondation. Les assemblages de diatomées montrent que la salinité des eaux de surface était nettement plus faible au moment de la sédimentation. La datation par radiocarbone indique que l'inondation s'est produite il y a entre 9160 et 9800 BP. Il existe une corrélation évidente entre l'unité argileuse et un dépôt passablement plus épais rencontré dans les sites de forage du Programme de sondage des fonds marins dans l'inlet Saanich.

INTRODUCTION

Outburst floods are relatively common occurrences in glacial landscapes. They can recur on an annual basis, tied to melting ice dams in glacially fed lakes. In Washington State, Glacial Lake Missoula emptied catastrophically at the end of the last glaciation and released meltwater floods about 40 times (Waitt and Richard, 1980) over a 2500 year period. Clague and Evans (1994) review examples of late Holocene outburst floods in several areas of the Canadian Cordillera that are related to glacial retreat or lifting of a glacier terminus damming a lake. The drainage of much larger lakes such as Glacial Lake Agassiz at the close of the last Laurentide glaciation has been tied to melting ice dams changing outflow drainage patterns and discharge rates (Broecker et al., 1989). The massive volumes of water released during outburst floods can be of great significance to the environment both locally and globally. Millennial-scale climatic oscillations such as the Younger

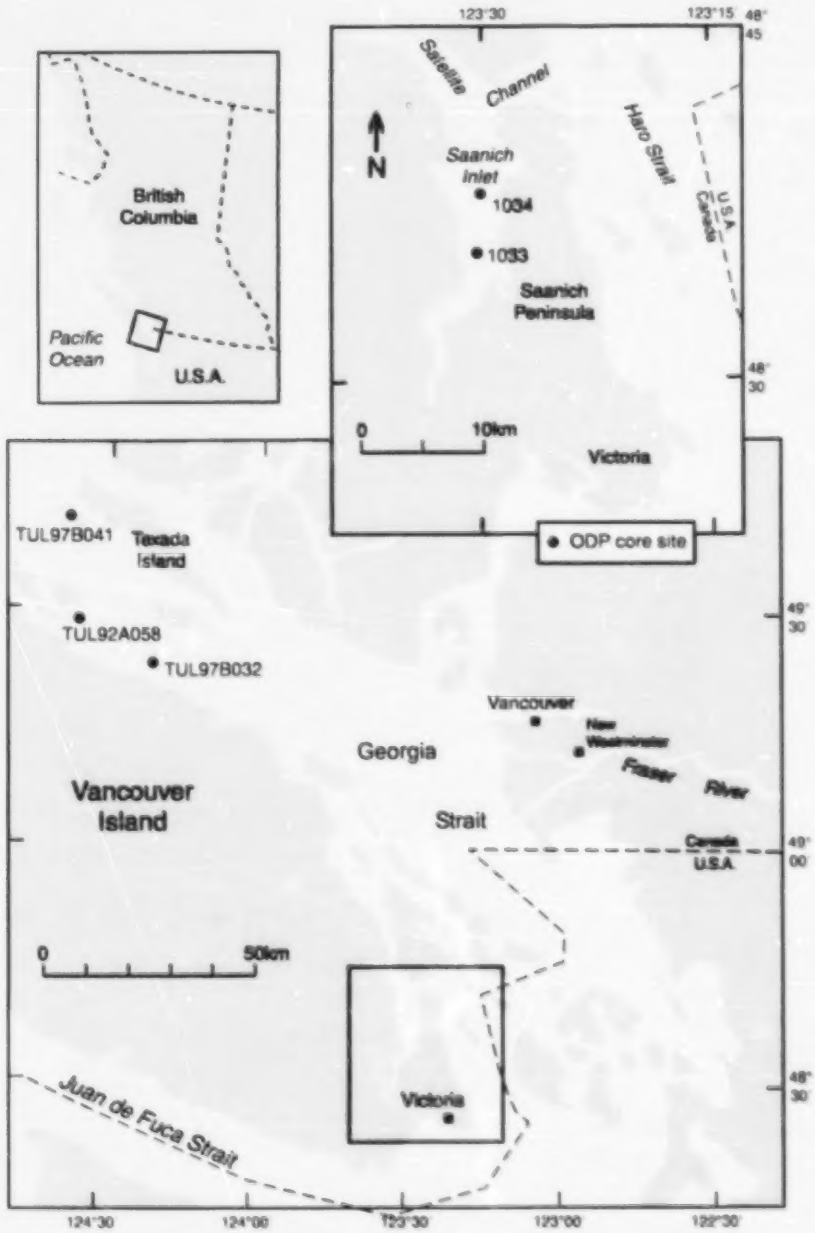

Figure 1. *Core locations in Strait of Georgia and ODP sites in Saanich Inlet.*

Dryas cold interval have been linked to meltwater floods of this type by the effect that very large volumes of freshwater input have on thermohaline oceanographic circulation (Broecker, 1998). The present study documents the submarine geological evidence for an outburst flood at the close of the Fraser Glaciation that affected most or all of the Strait of Georgia (Fig.1).

METHODS

A suite of cores was collected using a 1000 kg split piston coring system during regional surveys of the Georgia Basin in 1992 and 1997 (Barrie and Conway, 1999). The three cores used in this study were split, photographed, and visually logged prior to subsampling for grain-size analysis, microfaunal analyses (including diatoms (Lapointe, 1999), foraminifera, and pollen), and radiocarbon dating (Lawrence Livermore National Laboratory). Radiocarbon dates on shell material were corrected for an 800 year reservoir affect (Southon et al., 1990) and ages are here reported in radiocarbon years BP. Granulometry was done at the Pacific Geoscience Centre using a Micromeritics Sedigraph 5000D for mud fractions and a settling tube for sand fractions. Samples were taken for pollen analysis at 25 levels in all three cores. Selected samples from core TUL97B041 were subjected to pollen analysis using standard techniques (Faegri and Iversen, 1989; Hebda and Whitlock, 1997) to gain insight into the mode, environment, and timing of deposition of the clay layer. Palynomorph concentrations in the same core were also determined to detect possible changes in the rate of sediment accumulation (Stockmarr, 1972). Samples were taken at 2 to 3 cm resolution adjacent to and in the clay zone and at 5 to 10 cm resolution above and below it to locate clearly any differences in the pollen and spore assemblage. A particular focus was placed on pollen reworked or recycled from older deposits, a recognized indicator of water transport, in part from sources outside the region (*see* Hebda, 1977, for criteria).

RESULTS

Stratigraphic correlation of the cores was accomplished using the sedimentological character of the recovered sequences including colour, texture, and sedimentary structures as well as contained pollen and diatom assemblages and radiocarbon ages (Fig.2). At the base of the sequence, the glaciomarine sediments are roughly divisible into ice-proximal and ice-distal units. The gradational change to the overlying Holocene unit is indicated by an increasing silt and sand content expressed as overall coarsening-upward, grey to dark olive-grey colour change, and an absence of ice-rafted debris. A well defined clay bed up to 22 cm thick is found near the base of the Holocene sequence. Radiocarbon chronology is shown in Figure 2 and two dates closely bracket the clay layer. An age on wood of 9110 ± 60 radiocarbon years BP found 10 cm above the unit in core TUL92A058 and a corrected age of 9810 ± 50 radiocarbon years BP on paired bivalve shells (*Nuculana fossa*) located 20 cm below the unit in core TUL97B032 constrain the timing of the event (Fig. 2).

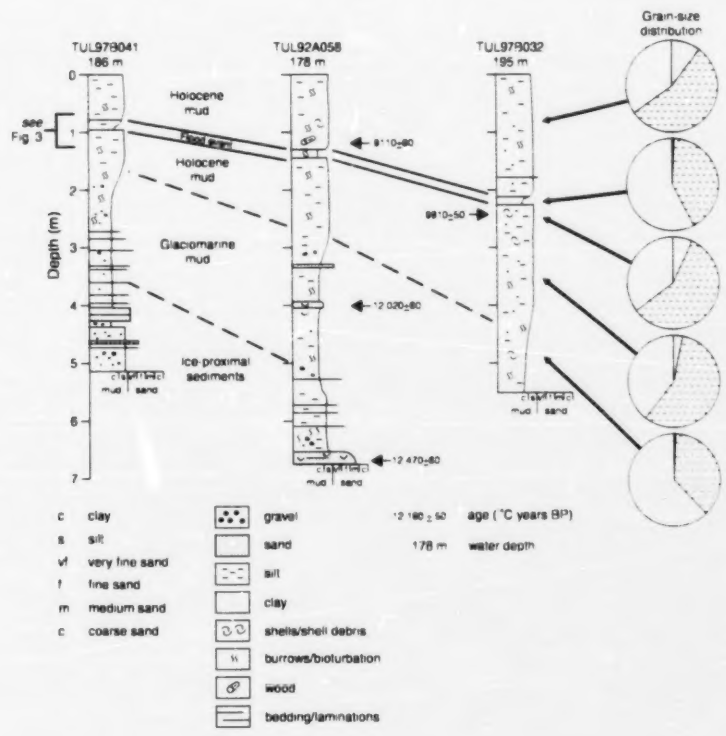

Figure 2.

Core types, radiocarbon ages, and correlation diagram. Grain-size distribution of subsamples is illustrated for core TUL97B032.

DESCRIPTION OF CLAY BED

The massive grey to dark grey (Munsell 5Y 5/1 to 5Y 4/1) clay bed contrasts in colour to the enclosing olive to dark olive-grey (Munsell 5Y 4/1 to 5Y 3/2) Holocene mud, above and below. The texture of the 10 to 22 cm thick bed is finer than that of the enclosing massive sediments. Analyzed subsamples of the clay unit contained less than 1% sand and more than 50% clay compared with 5% to 10% sand and 35% clay in the Holocene mud (Fig. 2). A sharp basal contact and a gradational upper contact define the lower and upper boundaries of the bed. In core Tul92A058, the contacts have been somewhat distorted and mixed by bioturbation. As a result the clay unit and adjacent sediments contain well preserved trace fossils.

DIATOM ASSEMBLAGES

Diatom assemblages contained 56 diatom species in 35 genera in core TUL92A058 and 51 species in 31 genera in core TUL97B032 (M. Lapointe, unpub. rept., 1999). Mean diatom concentrations were up to 3.8 million frustules/g of dry sediment in the Holocene mud. A brackish-water event of lowered salinity was identified at 138 cm in core Tul92a058 and at 224 cm in core TUL97B032 (M. Lapointe, unpub. rept., 1999), both within the clay bed. Brackish-water species recovered from these levels are planktonic and include *Aulacosiera granulata* and *Cyclotella stelligerina*. The enclosing Holocene sediments contained a flora of marine planktonic and benthic species consistent with Holocene environmental conditions. The appearance of *Fragilariopsis cyclindrus* at 356 cm in core TUL92A058 suggests lower water temperatures during deposition of the glaciomarine unit. The lower part of core TUL92A058 below 514 cm contained no diatoms, which probably indicates a glacial environment (M. Lapointe, unpub. rept., 1999).

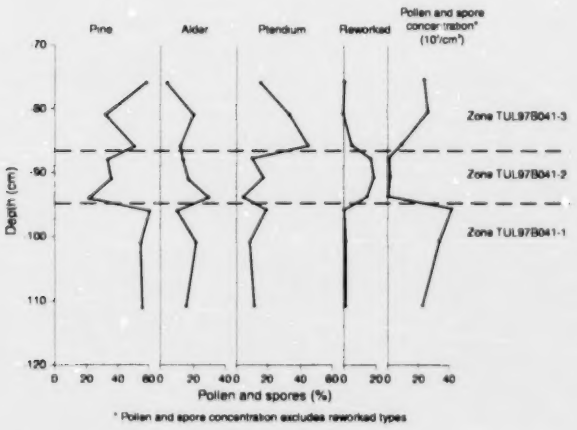

Figure 3. *Pollen and spore percentages and concentration of major types for core TUL97B041.*

POLLEN ANALYSES

The pollen and spore assemblages of the closely sampled interval of coreTUL97B041 can be divided in to three zones (Fig. 3). Zone TUL97B041-1 (111–96 cm depth) is dominated by pine pollen (54–60%) and *Pteridium* (bracken fern) spores (9–20%), with a notable component of alder pollen (10–22%). There is almost no reworked pollen (Fig. 3).

Zone TUL97B041-2 (95–87 cm depth), corresponds to the clay bed, and is characterized by abundant pine (21–34%) and alder (14–30%) pollen as well as a high proportion of reworked types (15–18%). Significantly, the reworked types include conifer grains as well as several deciduous taxa such as *Carya* (hickory), *Ulmus* (elm), and *Juglans* (walnut), which have not been indigenous to British Columbia since the Tertiary. *Pteridium* values (5–11%) are lower in this zone than in TUL97B041-1 although they increase slightly toward the top of the zone.

In zone TUL97B041-3 (87–70 cm depth), pine values and especially *Pteridium* values recover to and even exceeded those in TUL97B041-1 whereas reworked pollen disappears from the assemblage. Values for alder vary in the range of those of both zones 1 and 2.

The concentration of palynomorphs changes markedly in the three zones with TUL97B041-2 exhibiting very low concentrations especially near the base of the zone and zones 1 and 3 having similar relatively high concentrations. The sample at 94 cm has exceptionally low palynomorph concentrations particularly if reworked types are excluded from the total (Fig. 3). The concentration drops sharply from 41.7 x 10^3 palynomorphs/cm^3 to 0.8 x 10^3 palynomorphs/cm^3, a change that implies a sudden supply of additional sediment. A gradual increase in pollen and spore concentrations suggests a return to normal sedimentation between 88 and 86 cm in the core.

DISCUSSION

The three cores recovered from central Strait of Georgia allow a correlation of a regional clay unit through the sampled area (Fig. 1). The sediment grain size of the grey to dark grey bed is predominately clay, which contrasts sharply with the dominant sandy silt texture of the enclosing olive to olive-grey Holocene deposits (Fig. 2). The bed is covered by a greater thickness of sediments toward the south, which is unsurprising considering the modern depositional regime of the strait that is dominated by the Fraser River (Hart et al., 1998). The bounding contacts of the clay unit suggest a rapid onset of deposition, indicated by a sharp lower contact, and a more gradual return to typical marine conditions of deposition, indicated by a gradational upper contact. One of the cores (TUL92A058) shows well preserved bioturbation structures at the contact of the clay unit with the underlying mud (Fig. 2). These possibly represent traces of invertebrate escape structures created in response to increased sedimentation rates during deposition of the clay unit.

The pollen assemblage of zone TUL97B041-2 clearly reveals a change in sedimentation characteristics and sediment origins (Fig. 3). The marked increase in alder pollen and the sudden and persistent occurrence of reworked pollen clearly indicate that the clay layer is associated with disturbance. The composition of the reworked pollen assemblage, especially Tertiary deciduous taxa such as hickory, elm, and walnut, suggests that the disturbance and the sediments generated by it originated on mainland British Columbia because no Tertiary sediments are known from the vicinity of the core source area. The source of the reworked pollen may have been Fraser River delta topset sediments, which, at least in the modern condition, contain notable quantities of reworked pollen (Hebda, 1977). Alternatively, the reworked pollen may have originated directly from Tertiary deposits such as occur in southwestern British Columbia or even farther in the interior of British Columbia. The assemblage of zone TUL97B041-2 clearly reveals a change in sedimentation characteristics and sediment origins. The regional pollen signal remains as before, indicated by the abundance of pine and *Pteridium*. An identical pollen assemblage has been found in a clay unit near the base of the thick Holocene section in the ODP drill sites in Saanich Inlet (Blais-Stevens et al., in press) and will be discussed further.

The predominant nonreworked pollen types, pine, *Pteridium*, and alder, clearly place all the assemblages in the late Pleistocene to early Holocene interval (Hebda, 1995; Allen, 1995; Brown, 2000). Notable are the exceptionally high percentages of *Pteridium* never seen before in sediments of equivalent age. This assemblage suggests a very open, dry landscape onshore and also strongly suggests that the shoreline must have been nearby. From limited studies to date, *Pteridium* spores are not known to be transported by air in great quantities from the originating vegetation (Hebda, 1977; Allen et al., 1999). Of note, too, is the occurrence of a few (<0.5%) pollen grains of Douglas fir that suggest that early Holocene warming may have already taken place, or was taking place, at the time of deposition of the sediments. Reconnaissance-level analyses of cores TUL92A058 and TUL97B032 reveal a similar peak in the abundance of reworked conifer and Tertiary deciduous pollen types associated with the clay layer. The pollen assemblages of the more typical marine sediments above and below it are dominated by pine, alder, and *Pteridium*. On the basis of pollen analyses, the clay layer appears to be of the same age and origins at all three sites.

The presence of a well developed brackish-water signal in the diatom assemblage (M. Lapointe, unpub. rept., 1999) within the clay layer indicates that fresh water may have made surface waters brackish across the Strait of Georgia for a long enough period of time to develop an associated diatom flora. Alternatively, the contained diatom assemblage could possibly have the same source as the reworked pollen grains, which were transported with the floodwaters. The source of the brackish fauna could have been the Fraser River estuary, although the estuary and floodplain would have been much smaller at 10 000 BP when the river delta was only starting to develop and the river debouched into the Strait of Georgia near New Westminster (Clague et al., 1983). The fact that the brackish species are planktonic would also suggest that a flora of planktonic brackish-water diatoms existed in the surface waters during and possibly after the flood. Furthermore, the excellent preservation of the diatoms does not suggest highly turbulent transport by floodwaters but rather in situ deposition (M. Lapointe, written comm., 2000). Brackish-water conditions in the strait lasted long enough to have a large impact on the diatom flora. Consequently this would argue for a period of decreased surface-water salinity that lasted some weeks or even months.

The clay layer from the Georgia Basin cores correlates very well with deposits cored in Saanich Inlet during Ocean Drilling Program (ODP) Leg 169S that are situated 90 km south of core TUL97B032 (Fig. 1 and 4). At the Saanich Inlet sites, up 50 cm of clay, interpreted as representing an outburst flood deposit, is found at the base of the Holocene sequence (Blais-Stevens et al. in press). The clay beds in Strait of Georgia and Saanich Inlet deposits show essentially identical lithological unit, colour, and physical sedimentary structures — especially the nature of the bounding contacts. Furthermore, the stratigraphic position and palynological assemblage argue for the clay beds being the same deposit. The clay unit in Saanich Inlet is found near the base of a Holocene sequence up to 75 m thick. The best estimate of timing for emplacement of the flood event from the Saanich Inlet ODP cores is sometime shortly after 10 110 ± 50 radiocarbon years BP (Blais-Stevens et al., in press). In the Strait of Georgia cores, the estimate is sometime after 9810 ± 50 radiocarbon years BP. This chronology indicates a very close concordance

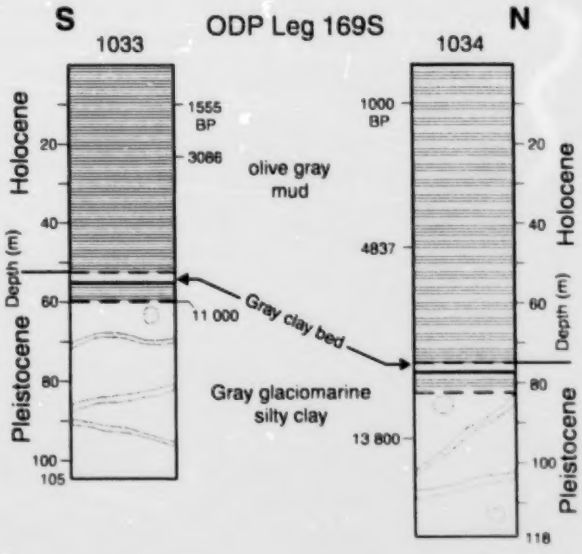

Figure 4. *Generalized lithology of ODP drill sites 1033 and 1034* after *Blais-Stevens et al. (in press). The distinctive clay horizon is found near the base of the olive laminated mud. Note that chronology shown on axes is in calendar years BP and that the best estimate for deposition of the clay bed is shortly after 10 110 50 radiocarbon years BP (Blais-Stevens et al., in press).*

in timing for the events. The strata immediately below the flood deposits in the Strait of Georgia and Saanich Inlet are dated to within 300 ± 100 radiocarbon years of one another. The sharp contact found in the Strait of Georgia cores occurs only once at the base of the clay bed in each core. The massive character of the unit above the sharp lower contact indicates continuous deposition from suspension. This suggests that the ice dam or dams that impounded meltwater in the Fraser Valley did not drain cyclically or seasonally, but were breached once.

CONCLUSIONS

1. About 10 000 radiocarbon years BP, a catastrophic release of impounded glacial lake water and meltwater flooded the Fraser Valley and the Strait of Georgia.
2. The flood dramatically changed the salinity and turbidity of the surface waters throughout the Strait of Georgia and left a clay layer covering much of the floor of the strait.
3. The clay unit correlates in sedimentology, micropaleontology and geochronology with a similar unit discovered by the ODP Leg 169S in Saanich Inlet, which recovered up to 50 cm of clay buried beneath over 50 m of Holocene sediment.

ACKNOWLEDGMENTS

David Gillan prepared the pollen samples for analysis. Richard Franklin provided the figures. The paper was improved by a critical review by Ralph G. Currie (GSC Pacific).

REFERENCES

Allen, G.B.
1995: Vegetation and climate history of southeast Vancouver Island, British Columbia; M.Sc. thesis, University of Victoria, Victoria, British Columbia.

Allen, G.B., Brown, K.J., and Hebda, R.J.
1999: Modern pollen spectra from south Vancouver Island; Canadian Journal of Botany, v. 77, p. 1–14.

Barrie, J.V. and Conway, K.W.
2000: A preliminary interpretation of surficial marine geology of central and northern Strait of Georgia; *in* Current Research 2000-A; Geological Survey of Canada, 7 p.

Blais-Stevens, A. Bornhold, B.D., Kemp, A.E.S., Dean, J.M., and Vaan, A.A.
in press: Overview of Late Quaternary stratigraphy in Saanich Inlet, British Columbia: results of Ocean Drilling Program Leg 169S; Marine Geology.

Broecker, W.S.
1998: What if the conveyor were to shut down? Reflections on a possible outcome of the great global experiment; GSA Today, v. 9, no. 1, p. 1–7.

Broecker, W.S., Kennett, J.P., Flower, B.P., Teller, J.T., Trumbore, S., Bonani, G., and Wolfli, W.
1989: Routing of meltwater from the Laurentide ice sheet during the Younger Dryas cold episode; Nature, v. 341, p. 318–321.

Brown, K.J.
2000: Late Quaternary vegetation, climate, fire history and GIS mapping of Holocene climates on southern Vancouver Island, British Columbia, Canada; Ph.D. thesis, University of Victoria, Victoria, British Columbia, 253 p.

Clague, J.J. and Evans, S.G.
1994: Formation and failure of natural dams in the Canadian Cordillera; Geological Survey of Canada, Bulletin 464, 35 p.

Clague, J.J., Luternauer, J.L., and Hebda, R.J.
1983: Sedimentary environments and postglacial history of the Fraser River Delta and lower Fraser Valley, British Columbia; Canadian Journal of Earth Sciences, v. 20, p. 1314–1326.

Faegri, K. and Iversen, J.
1989: Textbook of Pollen Analysis (fourth edition); Wiley, London, United Kingdom, 328 p.

Hart, B.S., Hamilton, T.S., and Barrie, J.V.
1998: Sedimentation on the Fraser Delta slope and prodelta, Canada, based on high-resolution seismic stratigraphy, lithofacies and ^{137}Cs fallout stratigraphy; Journal of Sedimentary Research, v. 68, p. 556–568.

Hebda, R.J.
1977: The paleoecology of a raised bog and associated deltaic sediments of the Fraser River Delta; Ph.D. thesis, University of British Columbia, Vancouver, British Columbia, 202 p.
1995: British Columbia vegetation and climate history with a focus on 6 ka BP; Géographie physique et Quaternaire, v. 49, p. 55–79.

Hebda, R.J. and Whitlock C.
1997: Environmental History; chapter 9 *in* The Rainforests of Home: Profile of a North American Bioregion, (ed.) P.K. Schoonmaker, B. Von Hagen, and E.C. Wolf; Island Press, Washington, p. 227–254.

Southon, J.R, Nelson, D.E., and Vogel, J.S.
1990: A record of past ocean-atmosphere radiocarbon differences from the northeast Pacific; Paleoceanography, v. 5, p. 197–206.

Stockmarr, J.
1972: Tablets with spores used in absolute pollen analysis; Pollen et Spores, v.13, p. 615–621.

Waitt, R.B.
1985: Case for periodic, colossal jokulhlaups from Pleistocene Lake Missoula; Bulletin, Geological Society of America, v. 96, p. 1271–1286.

Waitt, R.B. and Richard, B.
1980: About forty last-glacial Lake Missoula jökulhlaups through southern Washington; Journal of Geology, v. 88, p. 653–679.

Geological Survey of Canada Project 890052